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# Index Analysis Approach to Study the Surface Water Quality of Beas River, in Manali and Adjacent Area, Himachal Pradesh, India

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***Abstract*— The present research work aimed at using the application of Water Quality Index (WQI) in evaluating the quality of River Beas for public usage. Eighteen water samples during pre-monsoon and post-monsoon (2015) seasons were collected and were subjected for physicochemical and WQI analysis. The WQI of the study area ranged from 10.81 to 62.64.The WQI were categorized under good to excellent category and fit for consumption for pre monsoon and post monsoon season. The hydro-geo chemical facies evaluation indicated that most of the water samples during pre and post-monsoon are of Ca-Mg-Cl type. The present study demonstrated application of water quality index in understanding the quality of river water and appeared to be promising in the field of water quality management.**

***Keyword*- Environment Management, Hydro-geochemical, Physico-chemical, Water Quality Index.**

## I. INTRODUCTION

"Water is the elixir of life. Without it life is not possible" (Fetter, 2000). One of the important surface water resources is fresh river water. It plays an important role in integrating and organizing landscapes and shaping the ecological settings of basins (Kumar et al., 2011).

Rivers play a major role in assimilating or carrying of industrial and municipal wastewater, manure discharges and runoff from agricultural fields, roadways and streets, which are responsible for river pollution (Stroomberg et al., 1995; Ward et al., 1995). Rivers constitute to the main water resources for drinking, irrigation and industrial purposes, thus monitoring of water quality is essential.

Himachal Pradesh is a mountainous state situated in north-western part of Himalayas. It extends over a geographical area of 55, 673 sq. kms, which is 1.69 percent of the country's area and 10.54 percent of the Himalayan landmass (Census of India 2011). It is surrounded by Jammu and Kashmir in the north, Tibet on north/north east, Uttaranchal in the east/ south east, Haryana in south and Punjab in south west/ west.

Area-wise, Hamirpur is the smallest district of the Pradesh, which covers an area of 1,118 sq. kilometers (2.01%) and Lahaul & Spiti has the largest area of 13,835 sq. kilometres (24.85%). There is a network of perennial rivers in Himachal Pradesh, which have glaciers as their sources. Majority of the drainage of the state belongs to Indus River System. The Satluj, Beas, Ravi, Chenab, Spiti, Parbati, Pabbar, Tons and Giri are the main rivers of Himachal Pradesh.

The river water quality is highly variable by nature due to environmental conditions such as basin lithology, vegetation and climate (Awasthi et al., 2010; Sharma et al., 2015). Diverse uses of rivers are seriously impaired due to continuous growth of population, rapid developments in agriculture, mining, urbanization, industrialization and hydro-electrical generation activities, the river water contamination are becoming common phenomena (Sharma et al., 2016) in the region. Beas serving as major River for the state, flows through one of the main tourist hill spot town-Manali of Himachal Pradesh. Effluents from cottage, hotel industries, and municipal sewage agricultural, urban run-off are discharged into the river bringing about considerable change in the water quality.

Water quality index is one of the most effective tools to communicate information on the quality of water to the citizens (Amadi et al., 2010) and timely to implement the water quality improvement programmes efficiently .Water Quality Index (WQI) is commonly used for the detection and evaluation of water pollution and can be defined as "a rating reflecting the composite influence of different quality parameters on the overall quality of water." (Atulegwu et al., 2004).

The objective of the present research is to provide information on the physiochemical characteristics of river Beas in order to recognize the impacts of increased urbanization, tourism and unregulated waste discharge on the quality of the river as well as to discuss, its suitability for human consumption based on computed water quality index.

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## II. Description Of The Study Area

River Beas is a major tributary of the Indus river basin, it serves as main water resource for the state of Himachal Pradesh, has been selected for this study. It is located between 30022'40" N latitude to 33012'40" N and 75047'55" E to 79004'20" E longitude. River Beas originates from Beaskund, in Pir Panjal range near Rohtang pass at 13326 ft above mean sea level. Total length of river Beas is 470 km, out of which it flows 256 km in Himachal Pradesh. The principal tributaries are Solang, Manalsu, Sujjain, Fojal and Sarvari on the right bank and Alain, Duhagan, Chhaki, Haripur Nalah, Parbati, Tirthan and Sainj on the left bank. The climate in Manali is predominantly cold during winters and moderately cool during summers. The average temperature during summer is between 4 °C and 26 °C and between −15 ° C and 5 °C in the winter. The brief description (Table 1) and location map of the study area is given in the Fig 1.

**Table 1:**
**Brief description of the study area**

| | |
|---|---|
| Geographical Location | $31^0$ 6'12'' North and $77^0$10'20'' East |
| Geographical Area | 55,673 $km^2$ |
| Elevation | 2,319 m (7,608 ft) |
| Population (2011 Census) | 6,856,509 |
| Sex Ratio | 972 (for each 1000 male) |
| Population Density | 123 per $km^2$ |
| Literacy Rate | 82.80 % (2011) |
| Administrative Divisions | 12 Districts (Bilaspur Chamba Hamirpur, Kullu, Lahaul & Spiti, Kangra, Kinnaur, Mandi, Sirmour, Solan, Shimla, Una), 75 Tehsils, 34 Sub-Tehsils |
| State Capital | Shimla |
| Towns | 57 |
| Villages | 20,690 |
| Rural population | 61.76 lakhs |
| Urban population | 6.89 lakhs |
| Total Forest & Tree Cover of the State | 14,894 $km^2$ |
| Per Capita Forest & Tree Cover | 0.24 hac |
| Bio- Diversity- Plant Species<br>Animal Species | 3295 (7.32% of the Country)<br>5721 (7.41% of the Country) |
| Grazing Land / Pasture Available per Livestock | 0.26 hectares |
| Cultivable Land | 6.38 lakh hectares |
| Net Area Sown | 5.83 lakh hectares |

*(Source: Department of Environment Science and Technology, Shimla)*

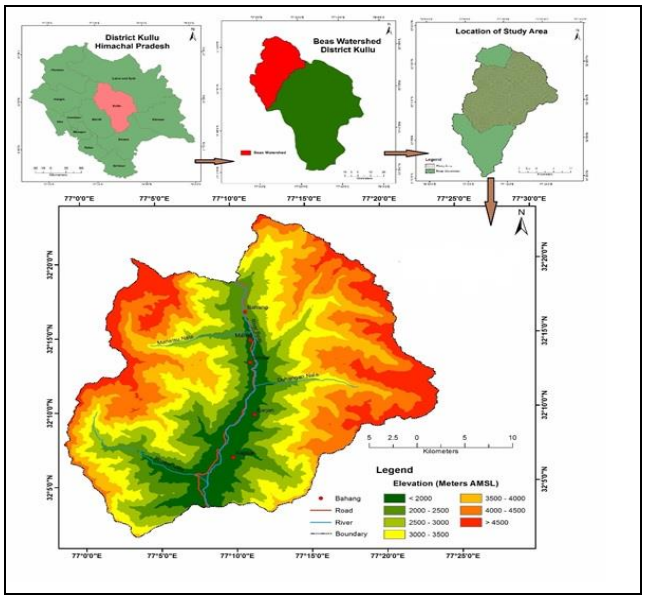


**Fig I: Location of the study area**

## III. Material And Method

It is very essential and important to test the water, before it is used for drinking, domestic, agricultural or industrial purpose. The present investigations consist of the analysis of important water quality parameters, which were collected randomly from 18 different locations during pre-monsoon and post-monsoon season (2015). Before sample collection, all the plastic bottles were thoroughly washed and sun-dried and were rinsed twice with the water sample to be collected. The bottles were then labelled and the co-ordinates of the sampling sites were noted. The water samples were clear, odorless and were analyzed for physicochemical testing. Samples were tested for parameters such as water temperature, EC, TDS, pH, TH, major cations $Mg^{2+}$, $Ca^{2+}$ and major anions $HCO_3^-$,$Cl^-$ $SO_4^{2-}$ , $NO_3^-$.Water temperature was measured on the site using mercury thermometer. Parameters like pH, EC, and TDS were analysed on the spot using potable water and soil analysis kit and $Mg^{2+}$, $Ca^{2+}$, $Cl^-$ and $HCO_3^-$ were analysed through volumetric analysis, $SO_4^{2-}$, $NO_3^-$ were analysed using spectrophotometer in laboratory following the standard procedures (APHA, 2005).

The results of Physico-chemical analysis of the water samples given in Table 2 shows the mean and standard deviation values of various parameters against desirable and permissible limits of of BIS, 2012 and WHO, 2011. All parameters except Nitrate were found within the permissible limits of drinking water quality standards.

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The Nitrate levels of few samples were found to be above permissible limits in both the season. During pre-monsoon minimum value was found to be 0.5mg/l to maximum value of 107 mg/l and for post-monsoon lowest value of 0.1 mg/l to highest value of 98.1 mg/l was recorded. The Chloride value for the pre-monsoon season was found to be 14.5 mg/l to highest value of 85.2 and for post-monsoon season the values ranged from 56.8 mg/l to 156.2 mg/l.

**Table 2:**
**Descriptive statistics of physicochemical parameters against desirable and permissible limit of water sample**

| Parameters | BIS-2012 | | WHO-2011 | | Pre-monsoon | | Post monsoon | |
|---|---|---|---|---|---|---|---|---|
| | D. limit | P.limit | D. limit | P.limit | Min | Maxi | Min | Maxi |
| pH | 6.5-8.5 | | 6.5-8.5 | | 6.4 | 8.1 | 6.5 | 8 |
| EC | ------ | | 1500µS/cm | | 72 | 521 | 57.1 | 108 |
| TDS | 500 | 2000 | 500 | 2000 | 46.8 | 338.6 | 37.1 | 70.2 |
| TH | 200 | 600 | -------- | | 28 | 186 | 8 | 70 |
| $Ca^{2+}$ | 75 | 200 | 75 | 200 | 6.72 | 38.6 | 8.4 | 23.5 |
| $Mg^{2+}$ | 30 | 100 | 50 | 100 | 1.4 | 22.9 | 0.31 | 7.32 |
| $HCO_3^-$ | -------- | | 500 | | 10 | 110 | 25 | 45 |
| $Cl^-$ | 250 | 1000 | 250 | 600 | 14.5 | 85.2 | 56.8 | 156.2 |
| $NO_3^-$ | 45 | | 45 | | 0 | 107.7 | 0 | 98.1 |
| $SO_4^{2-}$ | 200 | 400 | 200 | 400 | 18.9 | 47.3 | 0.61 | 9.2 |

### *A. Water Quality Index*

In the present study ten water quality parameters, namely pH, EC, TDS, TH, $Mg^{2+}$, $Ca^{2+}$, $HCO_3^-$, $SO_4^{2-}$, $NO_3^-$ and $Cl^-$ were used to calculate the WQI of the surface water samples. Various researches have used WQI approach to assess the water quality suitability for drinking purpose and for water quality management (Thakre et al., 2011; Singh et al., 2014, Herojeet et al., 2016). To calculate the WQI, the weight has been assigned for the physicochemical parameters according to the parameters relative importance in the overall quality of water for drinking water purposes. The assigned weight ranges from 1 to 5. The WQI has been calculated by using the standards of drinking water quality (BIS, 2012 and WHO, 2011). The weighted arithmetic index method (Brown et. al., 1970) has been used for the calculation of WQI of the waterbody.

Further, quality rating or sub index (qn ) was calculated using the following expression.

$$q\,n = 100[V\,n - V\,io] / [S\,n - V\,io]$$

(Let there be n water quality parameters and quality rating or subindex ($q_n$) corresponding to $n^{th}$ parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value.)

$q_n$ =Quality rating for the $n^{th}$ Water quality parameter
$V_n$=Estimated value of the $n^{th}$ parameter at a given sampling station.
Sn =Standard permissible value of the $n^{th}$ parameter.
$V_{io}$ = Ideal value of $n^{th}$ parameter in pure water. (i.e., 0 for all other parameters except the parameter pH (7.0)

Unit weight was calculated by a value inversely proportional to the recommended standard value **Sn** of the corresponding parameter.

$$Wn = K/Sn$$

Wn= unit weight for the $n^{th}$ parameters.
Sn= Standard value for $n^{th}$ parameters
K= Constant for proportionality.

The overall Water Quality Index was calculated by aggregating the quality rating with the unit weight linearly.

$$WQI = \sum q_n\, Wn / \sum Wn$$

The Water Quality Index is classified into 5 different water quality categories as summarized in Table 3. The maximum permissible value is 100, above this the water is classified unfit for human consumption.

**Table 3:**
**Water Quality Index (WQI) classification**

| No. | Water quality Index | Class |
|---|---|---|
| 1 | 0-25 | Excellent water quality |
| 2 | 26-50 | Good water quality |
| 3 | 51-75 | Poor water quality |
| 4 | 76-100 | Very Poor water quality |
| 5 | >100 | Unsuitable for drinking |

*Source: (Chatterji and Raziuddin 2002)*

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**Table 4:**
**Unit weightage of parameters by BIS (2012), WHO (2011).**

| Sr. No. | Parameters | Highest permitted value of water ($S_n$) | Unit Weight ($W_n$) |
|---|---|---|---|
| 1. | pH | 8.5 | 0.1470 |
| 2. | Electrical Conductivity | 1500 | 0.1176 |
| 3. | Total Dissolved Solids | 500 | 0.1470 |
| 4. | Total hardness | 300 | 0.0588 |
| 5. | Calcium | 75 | 0.0588 |
| 6. | Magnesium | 30 | 0.0294 |
| 7 | Chlorides | 250 | 0.0882 |
| 8. | Nitrate | 45 | 0.1470 |
| 9. | Sulphate | 200 | 0.1176 |
| 10. | Bicarbonate | 500 | 0.0882 |

The calculated unit weightage of each parameter based on the Indian drinking water standards (BIS, 2012 and WHO, 2011) is given in Table 4.

## IV. Results And Discussions

The values of Water Quality Index for the water samples of the study area is given in the Table 5. Most samples of both seasons were found in the range of good to excellent category. From the table it is seen that out of 18 water samples collected from the study area in the pre-monsoon season , 9 samples fall in good category of water quality and 7 samples fall under excellent category, which is from 0-25.Out of 18 samples only 2 samples fall in the category of poor water quality.

Similarly for the post- monsoon season, out of 18 water samples, 7 samples fall in good water quality and rest 11 samples fall in the category of excellent class.

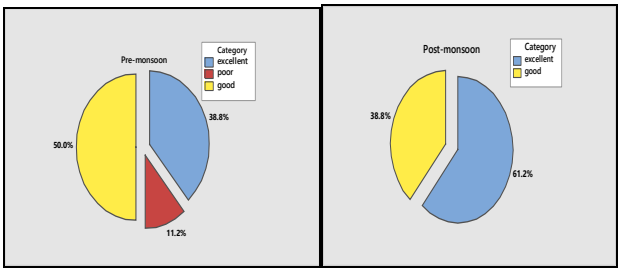


**Fig 2: WQI Categories of samples (%) in various seasons**

In Pre-monsoon 50% samples are of good quality, 38.8% falls under excellent category and only 11.2% samples are categorized into poor water quality and for the post-monsoon 38.8% samples are good quality and remaining 61.2% samples fall under excellent quality (Fig 2 and Fig 3).

**Table 5:**
**WQI for Pre-monsoon and Post-monsoon Season 2015**

| Sample no. | Pre-monsoon WQI- 2015 | | Post-monsoon WQI- 2015 | |
|---|---|---|---|---|
| | Value | Class | Value | Class |
| 1. | 33.41 | Good | 51.65 | Good |
| 2. | 37.39 | Good | 48.71 | Good |
| 3. | 31.85 | Good | 17.47 | Excellent |
| 4. | 38.87 | Good | 16.88 | Excellent |
| 5. | 47.48 | Good | 31.08 | Good |
| 6. | 62.64 | Poor | 21.83 | Excellent |
| 7. | 40.57 | Good | 12.24 | Excellent |
| 8. | 53.37 | Poor | 10.81 | Excellent |
| 9. | 45.41 | Good | 19.90 | Excellent |
| 10. | 42.63 | Good | 12.23 | Excellent |
| 11. | 40.59 | Good | 9.907 | Excellent |
| 12. | 15.62 | Excellent | 17.97 | Excellent |
| 13. | 15.05 | Excellent | 26.61 | Good |
| 14. | 13.63 | Excellent | 43.42 | Good |
| 15. | 25.21 | Excellent | 20.15 | Excellent |
| 16. | 19.96 | Excellent | 25.14 | Excellent |
| 17. | 18.61 | Excellent | 30.77 | Good |
| 18. | 18.05 | Excellent | 33.03 | Good |

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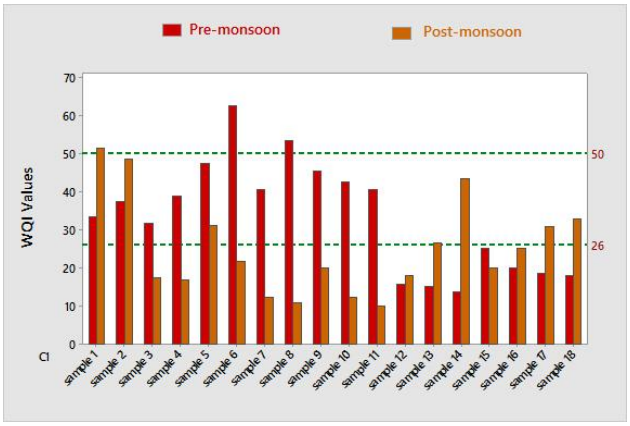


**Fig 3: WQI for surface water sampling of the study area, green line indicate the range of good category**

### *A. Hydrochemical Facies Of Surface Water In The Study Area.*

Hydrochemical Facies are distinct zones that have cations and anions concentrations, describable within defined composition categories. Piper (Piper, 1944) graphical representation method was used to access the nature of hydro-geochemistry of water (Fig 4& 5).Various research have used this plot to characterize the hydro-chemical nature of water (Herojeet et al., 2016; Thakur et al., 2016) This diagram consists of three distinct fields including two triangular fields and a diamond-shaped field. The cations expressed as percentage of total cations in meq/l as a single point on the left triangle while anions plot in the right triangle. Rockswork-15 software was used for plotting the Piper diagram

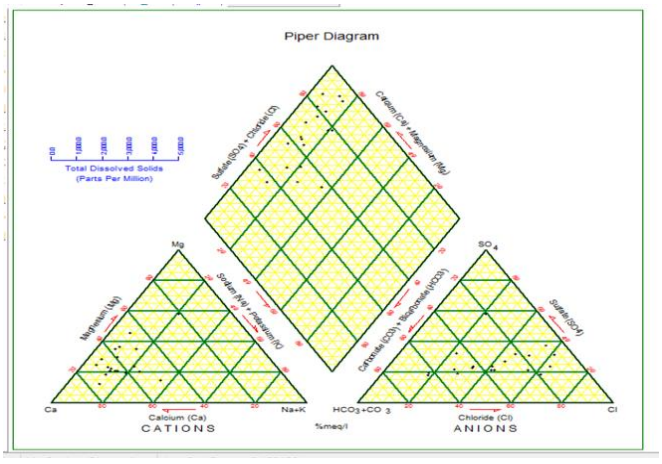


**Fig 4: Piper trilinear diagram for major ion chemistry for Pre-monsoon (2015) of the study area**

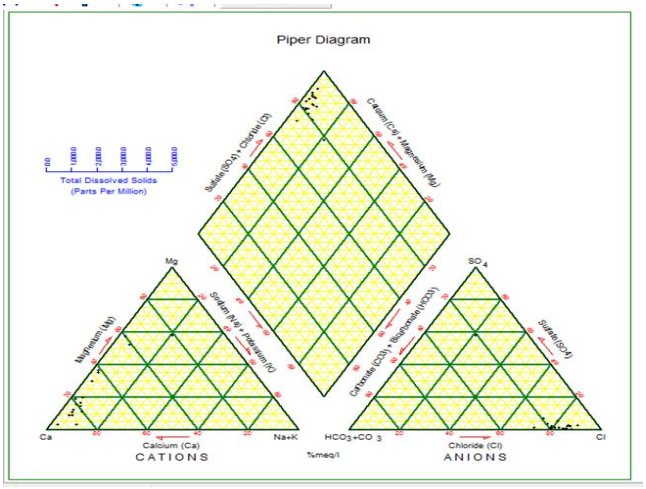


**Fig 5: Piper trilinear diagram for major ion chemistry for Post-monsoon (2015) of the study area.**

Plots of the analytical data of the water samples, collected from the study area during pre-monsoon season, clustered in the division 1, 4 and 6 of Piper diagram. Which shows that Alkaline Earth metal ($Ca^{2+}$ and $Mg^{2+}$) significantly exceeds the Alkali earth metals ($Na^{+}$ and $K^{+}$) and strong acids ($Cl^{-}$ and $SO_4^{2-}$) dominated weak acids ($HCO_3^{-}$ and $CO_3^{-}$) and non-carbonate hardness (secondary salinity) exceeds 50% i.e. chemical properties are dominated by alkaline earth and weak acids . And for the post-monsoon season the analytical data, clustered in the division 1, 4 of Piper diagram showing major dominance of $Ca^{2+}$ -$Mg^{2+}$ and Cl ions in the study area. Geo-chemical facies evaluation indicated that most of the waters in post-monsoon season of the study area are of $Ca^{2+}$-$Mg^{2+}$-$Cl^{-}$ type.

The dominance of chlorides during post-monsoon can be attributed due to the surface runoff from various sources into the rivers. Adding up more organic matter into the water bodies.

## V. Conclusion And Recommendations

Temporal variations have been observed in the study area and significant deteriorated conditions of water were detected during pre-monsoon season based on WQI. Further, assessment of physico-chemical parameters for its suitability for drinking purposes showed that most affected parameters were nitrate and chloride during post-monsoon season which could be attributed to the runoff from the nearby agricultural fields.

It was also observed during the sampling that the various outlets from the residential and commercial area were discharging wastewater directly into the river without subjecting to the treatment plants therefore installation of sewage treatment plants and their regular monitoring was recommended to prevent the outbreak of water borne diseases and to avoid the precarious situation in the area under investigation as the regular water quality monitoring program produces reliable data, which reflects the state of the water quality of a river.

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